Willamette National Forest

Burned Area Emergency Response

Terwilliger Fire

Soil Resource Assessment

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I. Objectives

- Assess changes in soil resource conditions resulting from the fire
- Determine if changed conditions result in potential threats to values at risk

The purpose of this assessment is to evaluate post-fire conditions from the Terwilliger wildfire and possible emergency conditions in burned areas caused by deterioration of soil properties and impacts to hydrologic processes, which leads to accelerated soil erosion. These impacts can contribute to long-term decline in soil quality.

II. Values at Risk

Resource	Description of threat
Soil Erosion and Soil Productivity	Loss of long-term soil productivity on NFS land

III. Observations

Burned Area Characterization

The Terwilliger fire started August 19th and burned 11,463 acres. The fire burned close to the forest floor resulting in minimal tree canopy scorching in the majority of the fire. Small islands burned with greater intensity resulting in moderate and high burn severity which created a mosaic of burn severity.

Soils

Dominant soils inside the fire perimeter are listed below (Table 1). The soil types are predominantly andisols and inceptisols with lithic modifiers. They are composed of shallow gravelly loamy sands formed from residuum and colluvium from volcanic parent materials. These areas consisted of steep slide-slopes and ridges with slopes ranging from 20 to 70 percent. The infiltration rate of these soils are high due to the coarse texture and gravel content. These soils have moderate to severe erosion potential due to the steep terrain.

Table 1 –Dominant Soils within the Terwilliger Fire

Soil Map Unit	Texture	Rock %	Erosion Rating	Acres	% of Fire
3	loamy sand to sandy loam	58	moderate-severe	2914	25%
602	loamy sand	45	severe	702	6%
16	loamy sand	45	moderate	834	7%
610	loamy sand	45	severe	972	8%
616	loamy sand	45	severe-moderate	491	4%
15	loam to sandy loam	28	moderate	468	4%
231	loamy sand	28	moderate	955	8%
9	loamy sand to sand	58	severe-very severe	276	2%
614	loamy sand	45	severe-moderate	450	4%
23	loamy sand	28	moderate	221	2%
1	Bedrock	100	none	187	2%

Resource Assessment

Methods

A combination of methods were used to assess soil conditions, including BARC imagery examination, field and flight observations, Soil Resource Inventory (SRI) data, and erosion potential modeling.

Verification of Burn Area Reflectance Classification Map

A Burned Area Reflectance Classification (BARC) map was provided on Oct 2nd from satellite imagery acquired by the Remote Sensing Applications Center (RSAC). A BARC map is a satellite-derived map of pre and post-fire vegetation conditions based on the relative change in near and mid-level infrared reflectance values. The BARC map has four burn intensity classes: high, moderate, low and unburned. Changes from pre- to post-fire vegetation are used as indicators to estimate soil burn severity as a function watershed response, however fire intensity is not primarily a reflection of wildfire effects on soils. Soil burn severity is the effect of fire at and below the ground surface, specifically how the fire changes the physical and chemical composition of the soils. Soil burn severity is a better indicator of overall

watershed response to burning and natural vegetative recovery after the fire than purely vegetation burn intensity.

Data collection was largely dependent on accessibility and safety. The Western and Southern areas of the fire were easily assessed, however due to the lack of roads in the wilderness, the Eastern portion was limited. Aerial reconnaissance of the fire was performed on October 10th. Field data was collected during the week by the soil scientist and other BAER personnel. Points outside the fire perimeter where used to determine the natural water repellency of soils in the surrounding unburned area. Collection of all burn severity points occurred from 10/9 – 10/12. Approximately 60 points were collected. Ash characteristics, duff and litter consumption, hydrophobicity, roots, fuel consumption were all assessed to determine soil burn severity by using guidelines outlined in 'Field Guide for Mapping Post-Fire Soil Burn Severity'(Parson et al., 2010). Mapped soil types were referenced from the Willamette National Forest Soil Resource Inventory (Legard & Meyer, 1973). The final soil burn severity map was developed in GIS using the BARC, flight photos, field data points, and aerial imagery.

Soil Erosion Potential

Soil erosion was analyzed by using a combination of surface erosion hazard ratings from the SRI data set, the final Burn Severity Map, and potential erosion modeling. Areas with severe erosion hazard ratings that overlapped with high/moderate were targeted for field visits and used for modeling.

Erosion and Sedimentation Prediction Tool- WEPP

The change in erosion potential and sediment yield from pre- to post fire conditions was estimated using the Forest Service Disturbed Water Erosion Prediction Project (WEPP) model. The general data requirements for Disturbed WEPP are climate data, soil texture, rock fragments, general vegetation type, slope gradient, horizontal slope length and burn severity. This tools are useful for comparing the relative difference between pre- and post-fire erosion potential. It should be noted the numbers generated are only estimations.

IV. Findings

Soil Burn Severity

In general the BARC map displayed an accurate picture of ground conditions of soil burn severity within the moderate and high areas, however poorly reflected actual ground condition in the low soil burn severity areas. No strong correlation was found between the rock outcrops and the high fire intensity reading either, which has the potential to give false readings. The fire creeped low to the floor and kept out of the high canopy in many low burn areas. The satellite translated the green canopy as unburned, however this was not the case. Several landscape observations confirmed this. Most of the unburned areas were changed to low burn which resulted in low soil burn severity in the majority of the fire (table 2, Figure 1).

Table 2. Final Soil Burn Severity

Soil Burn Severity	Acres	% of fire
High	173	2
Low	7468	65
Moderate	1262	11
Unburned	2560	22

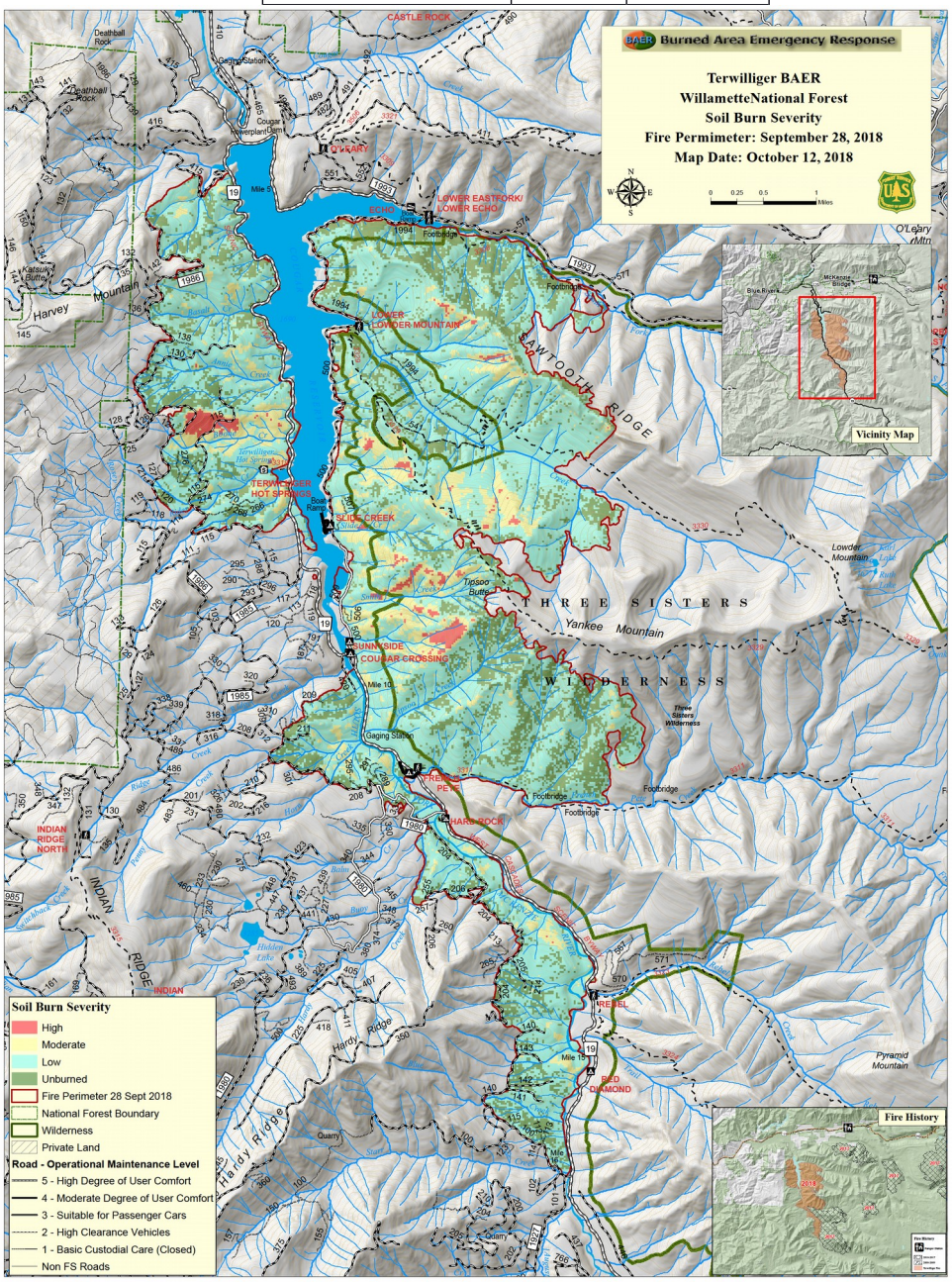

Figure 1- Final Burn Severity

Burn Severity Observations

Approximately **7,468** acres (65% of the fire) were rated as low burn severity. The ground surface was largely intact and the majority of the canopy /understory vegetation remained green and slightly charred. A seed source was likely present in the topsoil and natural regeneration is expected to occur in these areas. Soil structure and roots remain mostly unchanged. Moderate hydrophobicity was overserved in the top of the soil 2 cm of the soil surface. This was the case for unburned areas as well due to the natural hydrophobic properties of the soils. Rock outcrops accounted for a small portion of these areas.

Approximately **1,262** acres (11% of the fire) were rated as moderate soil burn severity. Finer fuels, surface litter, and tree canopy was mostly consumed. Gray, black ash or charred needles covered most of the ground. There is a high potential for effective ground cover from scorched needles or leaves remaining in the canopy in the moderate burn compared to the high burn areas. Many of these areas had already begun to receive fresh needle cast deposits. High soil hydrophobicity was observed at several points in the top 4 cm of the soil surface.

About **173** acres (2% of the fire) were rated as high soil burn severity. Much of the area within the high burn severity areas contained less than 10% ground cover and largely lacked canopy cover for future needle cast. Ash depth measured over 2 cm and high soil hydrophobicity was observed in the top 4 cm of the soil. Lack of ground cover combined with steep slopes leaves these soils susceptible to erosion.

Water Repellency

Unburned areas naturally displayed hydrophobicity due to the volcanic properties of these soils, and because of this it made it difficult to distinguish between fire affects and existing hydrophobicity. The high and moderate burn areas however continuously displayed high hydrophobicity. For this reason, high and moderate soil burn severity areas were assigned a high level of repellency. The low SBS were assigned as moderate repellency, and unburned as low water repellency due to the natural hydrophobic properties. The levels were assigned to capture the affects from the fire rather than only the natural water repellency characteristics (table 3).

Table 3- Water Repellency Acres

Water Repellency	Acres
High	1436
Moderate	7467
Low	2560

Soil Erosion Ratings

Soil Erosion ratings were generated by using a combination of surface soil erosion hazard ratings from SRI data and soil burn severity levels (table 4, figure 2). The initial erosion hazard ratings from SRI were adjusted based on field observations,

because ground coverage is not taken into account. The ratings are mostly driven by gradient and texture. The soils largely have good ground coverage within the fire perimeter under pre-fire conditions. Areas with high soil burn severity were given a high erosion rating because of the loss of ground coverage. Areas within moderate burn severity, combined with severe or moderate hazard ratings, were also given a high erosion risk. A detail matrix used to assign erosion values can be found in Appendix B.

Table 4- Soil Erosion Risk

Soil Erosion Risk	Acres
High	3,918
Moderate	7,280
Low	265
Total	11,463

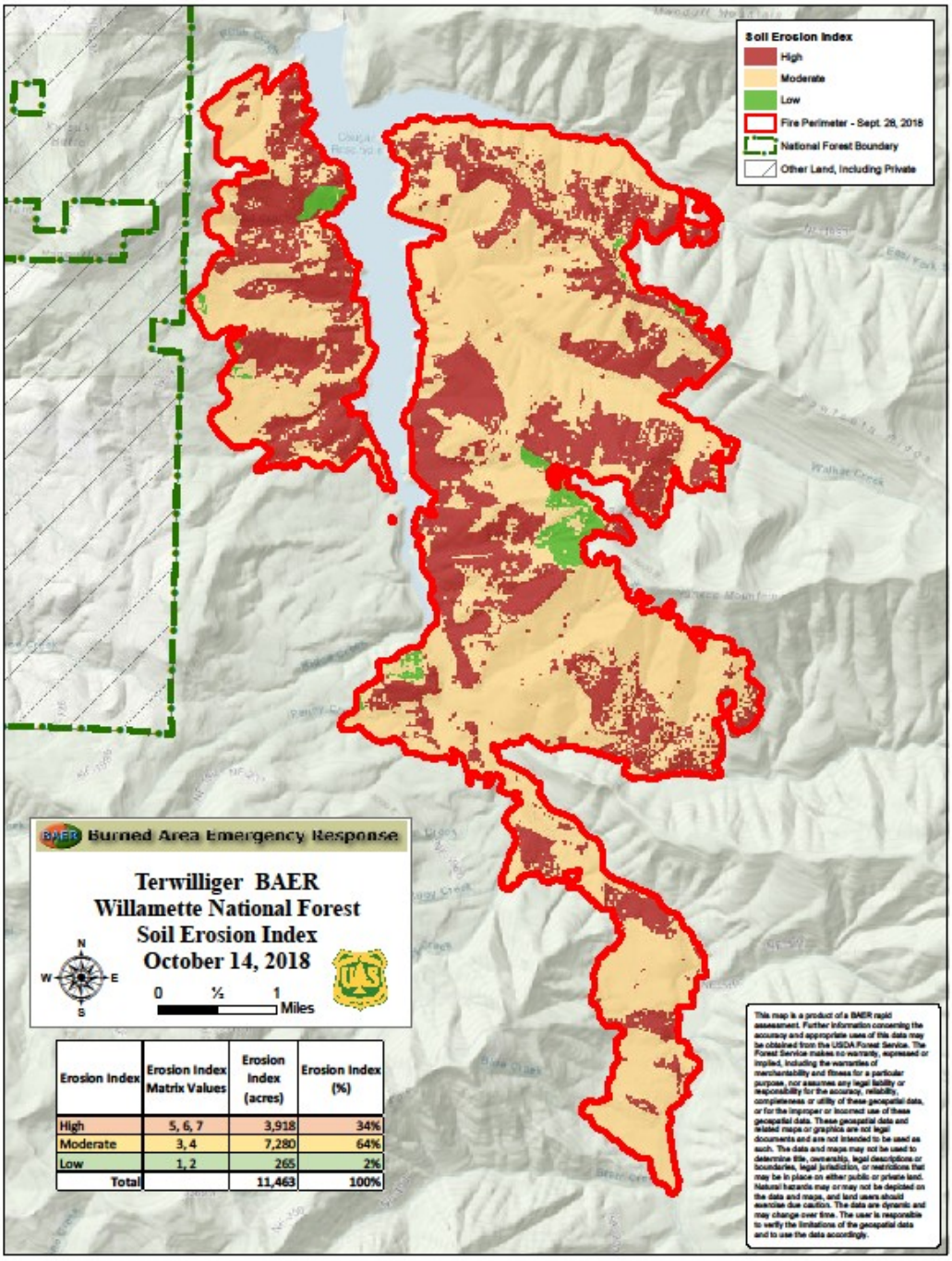

Figure 2- Soil Erosion Index Map

WEPP Results

The following assumptions of modeling parameters inputs are:

- Annual precipitation of 67.57 inches at 2263 ft. (using modified Cascadia Weather Station)
- A typical hillslope length of 500 ft.
- Hillslope gradients of 10% top slope, 45% slopes midway, and 20% slope toe slope
- Sandy loam texture with 50% course fragments

Table 5- Results- Erosion Potential (tons/Acre)

Year	Unburned	low	Moderate	High
1st	0	0.3	0.93	1.31

Averaged model estimates indicate that overall, there could be hill slope erosion increase of 0.93- 1.31 tons per acre basis in the first year post-fire from ground where soil burn severity was moderate or high (table 5). It is assumed only a portion of sediment will be delivered based on field observations such as; slope roughness, high amount of surface rock fragments and downed large woody debris that would function as sediment delivery interrupters. The high burn severity areas are mostly buffered by moderate and low burn severity, providing a buffer for sediment delivery. These estimated output numbers, along with low amount of high burn areas, as well the mosaic of the burn, a large-scale sediment response would not be expected.

IV. Assessment of Values at Risk

In general the fire resulted in a mosaic of low soil burn severity the ground surface was largely intact and the majority of the canopy /understory vegetation remained green and slightly charred. Partially consumed shrubs and larger fuels were scattered through which will help prevent major soil loss and act as sediment catches. There is no major concern for massive soil erosion in these areas due to the intact protective ground cover. The canopy in the low SBS patches was largely unburned and already was providing needles casts for soil organic matter replenishment. Most patches within the moderate areas contained sufficient amount of needles as well as fungus colonization.

Soils in the high burn areas displayed high water repellency and the litter floor was mostly consumed. There was no evidence of soil erosion (rill erosion and deposition) from prior small rain events. Lack of ground cover combined with steep slopes leaves these soils susceptible to erosion, however due to the patchiness of these areas, the high amount of surface rock fragments and downed large woody debris,

and since it only accounted for 2% of the fire this was not seen as a major threat to values at risk.

After analyzing the burn severity levels of the fire, the potential erosion numbers generated by WEPP, and field observations of ground cover and needle cast inputs, it is reasonable to conclude a large scale erosion response would not be expected.

Overall it was determined the treat of loss of soil productivity is moderate.

Value at Risk	Probability of Damage	Magnitude of Consequence	Risk Determination
Soil productivity	**Possible**	**Moderate**	**Intermediate**

V. Response Actions Recommended

No treatments recommended. Natural recovery is expected. Needle cast remaining in the trees of the majority of the fire will aid in infiltration, help prevent soil erosion, and replenish soil nutrients.

References

Hall, D., Elliot, W.J. 2009.Water Erosion Prediction Project (WEPP) Ver. 2009.09.17. http://forest. moscowfsl.wsu.edu/cgi-bin/fswepp/wd1/weppdist.pl?units=m. Moscow, ID: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Parsons, A., Robichaud, P.R., Lewis, S.A., Napper, C., Clark, J.T. 2010. "Field Guide for Mapping Post-Fire Soil Burn Severity". United States Department of Agriculture, Forest Service, Rocky Mountain Research Station, General Technical Report RMRS-GTR-243.

Legard, H.A., and LC. Meyer. 1973 "Willamette National Forest Soil Resource Inventory" United States Department of Agriculture, Forest Service, Willamette National Forest.

Appendix A. WEPP Inputs and Outputs

Location	CASCADIA R S OR + + Modified by Rock:Clime on October 15, 2018 from CASCADIA R S OR 351433 0 T MAX 45.13 50.45 54.72 60.94 66.55 72.43 80.22 80.74 75.49 64.29 52.06 45.78 deg F T MIN 30.56 32.57 34.19 37.26 41.69 46.96 48.62 47.76 44.01 39.45 35.38 32.62 deg F MEANP 9.19 7.61 7.53 5.52 4.42 2.88 0.86 1.45 2.90 4.87 10.12 10.15 in # WET 18.37 15.85 18.82 15.76 12.63 8.73 3.44 4.02 7.24 12.18 17.45 19.16 days Latitude 44.42 Longitude 122.46 Elevation 2263.0 ft				
Soil texture	sandy loam				
Element	Treatment	Gradient (%)	Length (ft)	Cover (%)	Rock (%)
Upper	mature forest	10 45	500	100	50
Lower	mature forest	45 10	500	100	50
Description					

Return Period	Precipitation (in.)	Runoff (in.)	Erosion (t ac^{-1})	Sediment (t ac^{-1})
2 year	76.18	1.01	0.05	0.0386
1 year	72.13	0.00	0.00	0.0000
Average	74.15	0.51	0.03	0.0178

Location	CASCADIA R S OR + Modified by Rock:Clime on October 15, 2018 from CASCADIA R S OR 351433 0 T MAX 45.13 50.45 54.72 60.94 66.55 72.43 80.22 80.74 75.49 64.29 52.06 45.78 deg F T MIN 30.56 32.57 34.19 37.26 41.69 46.96 48.62 47.76 44.01 39.45 35.38 32.62 deg F MEANP 9.19 7.61 7.53 5.52 4.42 2.88 0.86 1.45 2.90 4.87 10.12 10.15 in # WET 18.37 15.85 18.82 15.76 12.63 8.73 3.44 4.02 7.24 12.18 17.45 19.16 days Latitude 44.42 Longitude 122.46 Elevation 2263.0 ft				
Soil texture	sandy loam				
Element	Treatment	Gradient (%)	Length (ft)	Cover (%)	Rock (%)
Upper	low severity fire	10 45	500	85	50
Lower	low severity fire	45 20	500	85	50
Description					

Location	CASCADIA R S OR + + Modified by Rock:Clime on October 15, 2018 from CASCADIA R S OR 351433 0 T MAX 45.13 50.45 54.72 60.94 66.55 72.43 80.22 80.74 75.49 64.29 52.06 45.78 deg F T MIN 30.56 32.57 34.19 37.26 41.69 46.96 48.62 47.76 44.01 39.45 35.38 32.62 deg F MEANP 9.19 7.61 7.53 5.52 4.42 2.88 0.86 1.45 2.90 4.87 10.12 10.15 in # WET 18.37 15.85 18.82 15.76 12.63 8.73 3.44 4.02 7.24 12.18 17.45 19.16 days Latitude 44.42 Longitude 122.46 Elevation 2263.0 ft				
Soil texture	sandy loam				
Element	Treatment	Gradient (%)	Length (ft)	Cover (%)	Rock (%)
Upper	low severity fire	10 45	500	65	50
Lower	low severity fire	45 20	500	65	50
Description					

Return Period	Precipitation (in.)	Runoff (in.)	Erosion (t ac^{-1})	Sediment (t ac^{-1})
2 year	76.18	2.43	2.33	2.3305
1 year	72.13	0.94	0.93	0.9270
Average	74.15	1.68	1.63	1.6287

Location	CASCADIA R S OR + + Modified by Rock:Clime on October 15, 2018 from CASCADIA R S OR 351433 0 T MAX 45.13 50.45 54.72 60.94 66.55 72.43 80.22 80.74 75.49 64.29 52.06 45.78 deg F T MIN 30.56 32.57 34.19 37.26 41.69 46.96 48.62 47.76 44.01 39.45 35.38 32.62 deg F MEANP 9.19 7.61 7.53 5.52 4.42 2.88 0.86 1.45 2.90 4.87 10.12 10.15 in # WET 18.37 15.85 18.82 15.76 12.63 8.73 3.44 4.02 7.24 12.18 17.45 19.16 days Latitude 44.42 Longitude 122.46 Elevation 2263.0 ft				
Soil texture	sandy loam				
Element	Treatment	Gradient (%)	Length (ft)	Cover (%)	Rock (%)
Upper	high severity fire	10 45	500	35	50
Lower	high severity fire	45 20	500	35	50
Description					

Return Period	Precipitation (in.)	Runoff (in.)	Erosion (t ac^{-1})	Sediment (t ac^{-1})
2 year	76.18	2.31	3.80	3.5934
1 year	72.13	0.73	1.31	1.3120
Average	74.15	1.52	2.45	2.4520

Return Period	Precipitation (in.)	Runoff (in.)	Erosion (t ac^{-1})	Sediment (t ac^{-1})
2 year	76.18	2.02	1.15	1.1499
1 year	72.13	0.57	0.30	0.2982
Average	74.15	1.30	0.73	0.7253

Appendix B. Erosion risk Matrix

Soil Burn Severity		Hazard Rating	
Unburned	1	Severe to very severe; Severe; Severe to moderate	3
Low	2	Moderate to Severe; Moderate; Slight, local severe wind erosion	2
Moderate	3	Slight to moderate; Slight	1
Severe	4	N/A	0

Erosion Risk	Erosion risk Matrix Values
Low	1,2
Moderate	3, 4
High	5, 6,7